CHAPTER 2

Salmonid Use of the Estuary and Plume

The estuary and plume provide salmonids with a food-rich environment where they can undergo the physiological changes needed to make the transition from freshwater to saltwater habitats, and vice versa. Every salmonid that spawns in the Columbia River basin undergoes such a transformation twice in its lifetime—the first time during its first year of life (or soon after) when migrating out to sea, and the second time 1 to 3 years later, as an adult returning to spawn. The transition zone where juvenile salmonids undergo this transformation is thought to extend from the estuary itself to the near-shore ocean and plume habitats and into rich upwelling areas near the continental shelf (Casillas 1999).

The estuary and plume also serve as rich feeding grounds where juveniles have the opportunity for significant growth as they make the important transition from freshwater to seawater. Studies have shown that juvenile salmon released within the estuary and plume returned as larger adults and in greater numbers than juveniles released outside the transition zone (Casillas 1999). Thus, although juvenile salmonids face risks from a variety of threats in the estuary and plume (see Chapter 4), these environments can be highly beneficial. In the salmon life cycle, successful estuarine and plume residency by juveniles is critical for fast growth and the transition to a saltwater environment.

Clearly, the Columbia River estuary and plume are uniquely important to salmonids, and conditions in the estuary and plume undoubtedly affect salmonid survival. Yet the estuary and plume represent just one in a series of ecosystems that salmon use in their complex life cycle. Exploring the connections among these ecosystems, the habitats they provide, the salmonid species that use them, and the variety of life histories those salmonids display sheds further light on the role of the estuary and plume in the salmonid life cycle.

Salmonid Species in the Columbia River Basin

Before Euro-American settlement, the Columbia River basin was used extensively by six species of the family Salmonidae and the genus *Oncorhynchus*: chinook, chum, coho, and sockeye salmon plus two trout species: steelhead and sea-run cutthroat (Lichatowich 1999). Within these six species, 13 ESUs,[1] representing more than 150 populations of salmon and steelhead, have been listed as threatened or endangered under the federal Endangered Species Act (Bottom et al. 2005). All 13 of the ESUs use the estuary and plume as an essential link in their far-reaching life cycles.

It is estimated that historically up to 16 million salmon from perhaps hundreds of distinct populations returned to the Columbia River each year (Lichatowich 1999). This contrasts markedly with recent returns of salmon and steelhead adults, which have averaged about

[1] NOAA Fisheries has revised its species determinations for West Coast steelhead under the Endangered Species Act (ESA), delineating steelhead-only “distinct population segments” (DPSs). The former steelhead ESUs included both anadromous steelhead trout and resident, non-anadromous rainbow trout, but NOAA Fisheries listed only the anadromous steelhead. The steelhead DPS does not include rainbow trout, which are under the jurisdiction of the U.S. Fish and Wildlife Service. In January 2006, NOAA Fisheries listed five Columbia River basin steelhead DPSs as threatened (71 FR 834). To avoid confusion, references to ESUs in this estuary recovery plan module imply the steelhead DPSs as well.

1.7 million, with 65 to 75 percent of those fish being of hatchery origin.[2] For 2006, NOAA Fisheries scientists estimated that about 168 million juveniles would enter the estuary (Ferguson 2006b). This suggests that only 1 percent of the juveniles entering the estuary will return as adults and 99 percent are lost as a result of all the limiting factors (human and natural) in the estuary, plume, nearshore, and ocean.

Life History Types and Strategies

In discussing salmonids, fish scientists commonly refer to ocean type and stream type to distinguish two main freshwater rearing strategies. Ocean-type salmonids are characterized by migration to sea early in their first year of life, after spending only a short period in freshwater (Fresh et al. 2005). Ocean types may rear in the estuary for weeks or months, making extensive use of shallow, vegetated habitats such as marshes and swamps, where significant changes in flow and habitat have occurred (Fresh et al. 2005). Conversely, stream-type salmonids are characterized by migration to sea after rearing for more extended periods in freshwater, usually at least 1 year (Fresh et al. 2005). Table 2-1 shows the general characteristics of ocean-type and stream-type ESUs.

TABLE 2-1
Characteristics of Ocean- and Stream-Type Salmonids

Attribute	Ocean-Type Fish: fall chinook, chum	Stream-Type Fish: coho, spring chinook, steelhead
Residency time	Short freshwater residence Longer estuarine residence Longer ocean residence	Long freshwater residence (>1 year) Shorter estuarine residence Shorter ocean residence
Size at estuary entry	Smaller	Larger
Primary habitat use	Shallow-water estuarine habitats, especially vegetated ones	Deeper, main-channel estuarine habitats; use plume more extensively

Adapted from Fresh et al. 2005.

In the Columbia River estuary, both ocean- and stream-type salmonids experience significant mortality. However, because the two types typically spend different amounts of time in the estuary and plume environments and use different habitats, they are subject to somewhat different combinations of threats and opportunities.

For ocean-type juveniles, mortality is believed to be related most closely to lack of habitat, changes in food availability, and the presence of contaminants, including persistent, bioaccumulative contaminants present in sediments in the shallow-water habitats where ocean-type juveniles rear in the estuary. Stream types are affected by these same factors, although presumably to a lesser degree because of their shorter residency times in the estuary. However, stream types are particularly vulnerable to bird predation in the estuary because they tend to use the deeper, less turbid channel areas located near habitat preferred by piscivorous birds (Fresh et al. 2005), and they are subject to pinniped predation when they return to the estuary as adults. Also, scientists at NOAA/NMFS's Northwest Fisheries Science Center now hypothesize that larger numbers of stream-type yearling juveniles are

[2] This is an informal estimate made by several knowledgeable experts; determining the ratio of hatchery-origin fish with more certainty would require stock-by-stock run calculations averaged over many years.

susceptible to predation by northern pikeminnow than was previously thought; this predation occurs as the juveniles move into the shallows behind structures such as pilings or pile dikes to forage (Casillas 2007). Additionally, stream-type salmonids are thought to use the low-salinity gradients of the plume to achieve growth and gradually acclimate to saltwater. Changes in flow and sediment delivery in the plume may affect stream-type juveniles in a way similar to how estuary conditions affect ocean-type juveniles; however, additional research is needed to determine more precisely how stream types use the plume (Casillas 2006).

Fish scientists also describe salmonids in terms of the life history strategies they employ, meaning a population's unique pattern of preferred spawning substrate, habitat use, migration timing, length of estuarine and marine residency, and so on. For thousands of years, Columbia River salmonids exhibited great diversity in life history strategies, exploiting a wide array of the habitat niches available to them. This rich diversity in life history strategies allowed salmonids to persist as species for millennia even when individual populations were wiped out by disease or natural disturbances such as volcanic eruptions.

Table 2-2 identifies the six basic life history strategies used by salmon and steelhead in the Columbia River and their general attributes.

TABLE 2-2
Life History Strategies and Their Attributes

Life History Strategy	Attributes
Early fry	Freshwater rearing: 0 - 60 days Size at estuarine entry: <50 mm Time of estuarine entry: March - April Estuarine residence time: 0 - 40 days
Late fry	Freshwater rearing: 20 - 60 days Size at estuarine entry: <60 mm Time of estuarine entry: May - June, present through Sept. Estuarine residence time: <50 days
Early fingerling	Freshwater rearing: 60 - 120 days Size at estuarine entry: 60 - 100 mm Time of estuarine entry: April - May Estuarine residence time: <50 days
Late fingerling	Freshwater rearing: 50 - 180 days Size at estuarine entry: 60 - 130 mm Time of estuarine entry: June - October, present through winter Estuarine residence time: 0 - 80 days
Subyearling (smolt)	Freshwater rearing: 20 - 180 days Size at estuarine entry: 70 - 130 mm Time of estuarine entry: April - October Estuarine residence time: <20 days
Yearling	Freshwater rearing: >1 year Size at estuarine entry: >100 mm Time of estuarine entry: February - May Estuarine residence time: <20 days

Adapted from Fresh et al. 2005.

Changes in Life History Diversity

The 13 listed ESUs in the Columbia River express much less diversity in life history strategies now than they did historically. Formerly, both ocean- and stream-type salmonids entered the estuary and plume throughout the year, at a great variety of sizes, which reflected the various life history strategies in Table 2-2. Today juveniles tend to arrive in pulses and are more uniform in size.

TABLE 2-3
Linkage between Salmonid ESU, Dominant Life History Type, and Life History Strategy

ESU	Life History Type	Historical and Current Life History Strategies					
		Early Fry	Late Fry	Early Fingerling	Late Fingerling	Sub-yearling	Yearling
Columbia River chum salmon	Ocean	Abundant	Abundant	Absent	Absent	Absent	Absent
Snake River sockeye salmon	Stream	Absent	Absent	Absent	Absent	Rare	Abundant
Lower Columbia River coho salmon	Stream	Historically rare, currently absent	Historically rare, currently absent	Historically rare, currently absent	Historically rare, currently absent	Rare	Abundant
Upper Columbia River steelhead	Stream	Absent	Absent	Absent	Absent	Historically rare, currently absent	Abundant
Snake River steelhead	Stream	Absent	Absent	Absent	Absent	Historically rare, currently absent	Abundant
Lower Columbia River steelhead	Stream	Absent	Absent	Absent	Historically rare, currently absent	Historically medium, currently rare	Abundant
Middle Columbia River steelhead	Stream	Absent	Absent	Historically rare, currently absent	Historically rare, currently absent	Historically medium, currently rare	Abundant
Upper Willamette River steelhead	Stream	Absent	Absent	Absent	Absent	Historically rare, currently absent	Abundant
Snake River fall chinook salmon	Ocean	Absent	Absent	Historically medium, currently rare	Historically medium, currently rare	Abundant	Historically rare, currently medium
Upper Willamette River chinook salmon	Ocean	Historically rare, currently absent	Historically rare, currently absent	Historically medium, currently rare	Historically medium, currently rare	Historically rare, currently medium	Abundant
Lower Columbia River chinook salmon	Ocean	Historically medium, currently rare	Historically medium, currently rare	Historically medium, currently rare	Historically medium, currently rare	Historically medium, currently abundant	Rare
Upper Columbia River spring chinook salmon	Stream	Absent	Absent	Historically rare, currently absent	Historically rare, currently absent	Rare	Abundant
Snake River spring/summer chinook salmon	Stream	Absent	Absent	Historically rare, currently absent	Historically rare, currently absent	Rare	Abundant

Adapted from Fresh et al. 2005.

Table 2-3 shows losses in life history diversity in the Columbia River. The table identifies the dominant life history type (ocean vs. stream) and strategies for each ESU, the prevalence of each life history strategy, and whether that prevalence has changed from historical times to the present. The number of life history strategies employed by some ESUs, such as Columbia River chum, have not changed. But for other ESUs—notably the Lower Columbia River coho—several life history strategies that used to exist have been lost.

Losses in life history diversity can also be seen in Figure 2-1, which compares historical and current estuarine life history types for one brood year of chinook salmon. The figure shows a reduction in the number of strategies available in the contemporary versus historical estimates.

Some of the losses in salmonid life history diversity are attributable to habitat alterations throughout the Columbia River basin that have eliminated entire populations of salmon and steelhead. In other cases, hatcheries and harvest impacts have reduced the health and genetic makeup of species. As a result, many of the populations currently using the estuary and plume are significantly different than the fish that historically used the various habitats available to them, and some existing habitats may not be being used by salmonids at all.

Relationship of the Estuary to the Columbia River Basin

In 2005, scientists working at NOAA/NMFS's Northwest Fisheries Science Center published a technical memorandum that establishes an ecologically based conceptual framework for understanding the estuary within the larger context of the Columbia River basin. In *Salmon at River's End: The Role of the Estuary in the Decline and Recovery of Columbia River Salmon*, Bottom et al. (2005) hypothesize that Columbia River salmon's resilience to natural environmental variability is embodied in population and life history diversity, which maximizes the ability of populations to exploit available estuarine rearing habitats. Bottom et al.'s conceptual framework is based on Sinclair's (1988) member/vagrant theory, which proposes general principles for understanding marine species with complex life cycles. The member/vagrant theory serves as a useful tool for evaluating salmon's specific needs in estuaries in relation to the entire continuum of their habitat needs throughout their complex life cycles (Bottom et al. 2005).

Bottom et al. (2005) hypothesize that how an individual salmon or steelhead uses the ecosystems it encounters—when juveniles migrate, how big they are, what habitats they use, and how long they stay in a particular habitat—correlates directly to the discrete population of fish that individual is part of. In other words, different populations within ESUs employ different life history strategies. For example, two populations of steelhead within an ESU may produce juveniles of different sizes that enter the estuary at different times, and these juveniles may use distinct habitats that may be available only at that particular time.

Considering that the estuary is just one of three major ecosystems used by salmon and steelhead, the member/vagrant theory implies that how juveniles migrate and use estuarine habitat may depend as much on the status of upriver habitats and corresponding populations as on environmental conditions in the estuary itself (Bottom et al. 2005). In other words, if there is a close relationship between particular geographical features in the estuary and the life history of a discrete salmonid population, use of the estuary may reflect the abundance and life history strategy of the associated population, which is in part a function of upstream conditions. Thus, if salmonid migration and rearing behaviors in the estuary are linked to specific geographic features and those features are reduced or eliminated, mortality in the population that uses those features increases (Bottom et al. 2005). By the same token, if salmonid populations are lost because of other factors (such as blockage by dams), habitats in the estuary may be left unoccupied.

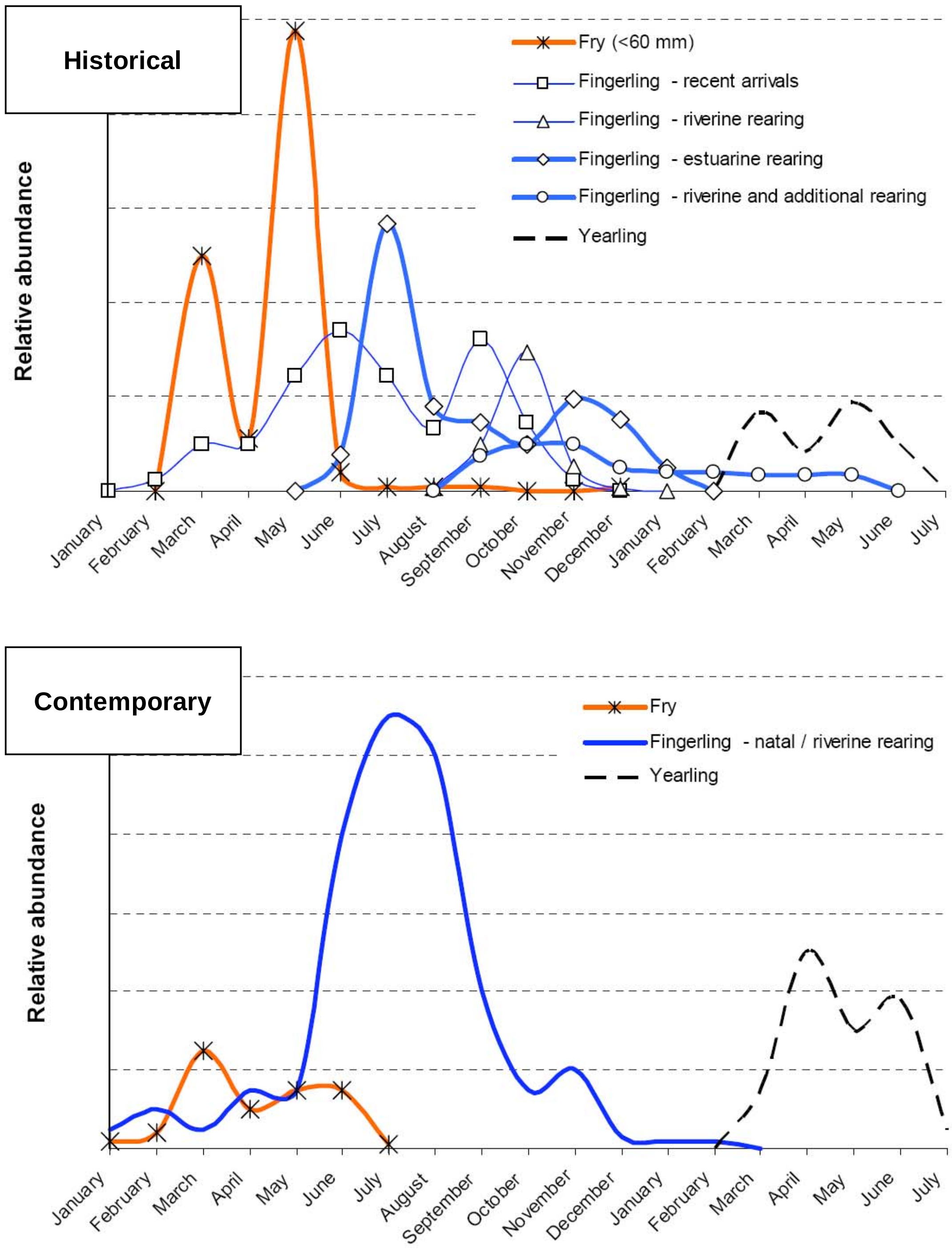

FIGURE 2-1
Historical and Contemporary Early Life History Types of Chinook Salmon in the Columbia River Estuary
(Reprinted from Fresh et al. 2005.)

The implication for salmon recovery in the Columbia River basin is that habitat use by salmonids must be considered from a multi-ecosystem perspective if we are to understand which components of each ecosystem—tributaries, mainstem, estuary, plume, nearshore, and ocean—are limiting the overall performance of salmon.

Summary

Since 1991, 13 Columbia River ESUs have been listed as threatened or endangered under the federal Endangered Species Act. During their complex life cycles, listed salmon and steelhead rely on many diverse ecosystems, from tributaries to ocean environments, that span hundreds or thousands of miles. For recovery efforts to be successful, it is necessary to understand salmonids' requirements during all stages of their life cycles. Thus, although the estuary and plume represent important stages in the salmonid life cycle, these ecosystems must be considered within the context of other life cycle stages if management actions are to be effective. Perhaps most central to the recovery of listed ESUs is the importance of conserving biological diversity and the native ecosystems it depends on (Bottom et al. 2005).